Article

Offsite Manufacturing Construction: A Big Opportunity for Housing Delivery in Nigeria

Kolo, Shaba James, Pour-Rahimian, Farzad and Goulding, Jack Steven

Kolo, Shaba James, Pour-Rahimian, Farzad ORCID: 0000-0001-7443-4723 and Goulding, Jack Steven (2014) Offsite Manufacturing Construction: A Big Opportunity for Housing Delivery in Nigeria. Procedia Engineering, 85 . pp. 319-327. ISSN 18777058

Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 85 (2014) 319 – 327

Procedia Engineering

www.elsevier.com/locate/procedia

Creative Construction Conference 2014, CC2014

Offsite manufacturing construction: a big opportunity for housing delivery in Nigeria

Shaba James Kolo, Farzad Pour Rahimian*, Jack Steven Goulding

The Grenfell-Baines School of Architecture, Construction and Environment, University of Central Lancashire, Preston PR1 2HE, UK

Abstract

The problem of housing delivery is of great concern in many countries of the world. This problem is more predominant in developing countries and Nigeria is not an exception. In Nigeria, this challenge has been magnified as a result of myriad of issues, e.g. high population growth rate, shortage of necessary skills, disintegrated supply chain etc. Seminal literature has proven that offsite manufacturing (OSM) can help improve housing delivery efforts both in terms of quantity and quality. The purpose of the research was to investigate the current housing delivery problems in Nigeria and evaluate the feasibility of adopting OSM. To achieve this, the study conducted substantial literature review to explore the benefits of OSM, identify the problems of housing delivery in Nigeria and explore different dimensions and the issues that can be associated with using OSM in Nigeria. The results revealed that there are a good number of benefits promised by OSM; notable among these benefits are: less wastage on site, faster construction time, quality improvement and reduction in wet trades. Moreover, some of the problems of housing delivery in Nigeria identified included: skills shortage, reliance on conventional construction techniques, slow pace of construction, and low quality of housing. The study also showed that adaptation of OSM has been quite useful in other countries facing the similar issues of housing shortage, e.g. Malaysia. As such, it is argued that OSM can improve skills shortages, improve the speed of construction, improve the overall quality of housing and help eliminate wet trades. For the problems of housing delivery to be tackled in Nigeria, it is important to undertake additional research to identify the benefits, barriers and context-specific ways of adopting OSM in Nigeria.

Peer-review under responsibility of the Diamond Congress Kft.

Keywords: housing delivery; housing shortage; Nigeria; offsite manufacturing;

* Corresponding author. Tel.: +44-1772-893-215; fax: +44-1772-892-916.
E-mail address: fpour-rahimian@uclan.ac.uk

Peer-review under responsibility of the Diamond Congress Kft.
doi:10.1016/j.proeng.2014.10.557

1. Introduction

Nigeria currently has a population that is put at over 140 million and this figure is on the increase at an annual growth rate of about 3.2% [1]. As a result, the country has a very large and ever-increasing housing deficit which stood at approximately 8 million housing units in 1991 and between 12 to 14 million housing units in 2007 [2]. The problem of housing deficit in Nigeria is as a result of rapid growth in population, skills shortages, high cost of building materials, logistical challenges etc.[3]. As a result of these problems, there is a wide gap between housing demand and housing supply in Nigeria [4-6]. There is work going on to reduce the current housing deficit in Nigeria but there is still so much work that needs to be done.

In the UK for instance, a good number of reports advocated for change within the built environment. Notable among these reports are the Latham report of 1994 (Constructing the Team) and the Egan report of 1998 (Rethinking Construction). As a result, there was a strong need for the construction industry to view construction as a manufacturing process [7]. This call for change is not peculiar with the UK only. In Nigeria, there have been suggestions that emphasis should be laid on other forms of construction such as prefab building [8]. Preliminary interviews with experts in the Nigerian construction industry showed that, in order to solve the problem of inadequate housing, there is the need for a shift from the conventional systems of construction to a more adaptable and faster way of construction. As such, 'Dry Construction' has been recommended by these experts [9, 10]. Dry Construction is described as a method of construction where majority of the components of the building are pre-fabricated off site and brought to site for assembling [10]. As identified by [Fussell, Blismas [11], Experian and SamiConsulting [12], Blismas, Wakefield [13], Azman, Ahamad [14]], there are opportunities for greater use of offsite manufacturing in the area of housing delivery. In countries like UK, USA, Japan, Scandinavian Counties, Australia, New Zealand, Malaysia etc., OSM has been adopted as a means of improving construction processes and also to improve housing delivery efforts [13, 15-19].

2. Problems of Housing in Nigeria

Housing (adequate shelter) is seen world-wide as one of the basic necessities of life and a pre-requisite to the survival of man. It is also important to the welfare, survival and health of individuals [5]. As opined by Olayiwola, Adeleye [20], housing remains one of the best indicators of a person's standard of living and his or her place in the society. In spite of the high importance given to housing, it is unfortunate that only 10% of Nigerians who desire houses can afford to acquire it either by purchase or personal construction, this is very low compared to 72% USA, 78% UK, 60% China, 54% Korea and 92% Singapore [1]. The problem of housing in Nigeria is caused by a number of factors [4, 21-24]. Among these problems are; rural-urban migration, high cost of building materials, inadequate regulatory and legal environment affect housing development, poor housing finance structures, skills shortage, limited diversity in construction processes and over reliance on cement [3, 25-27]. Some of the problems are highlighted below;

2.1. High Population Growth

Akinmoladun and Oluwoye [28] argued that the origin of housing inadequacy in Nigeria was as a result of high population growth rate experienced in the country which exceeds the rate of economic growth experienced in the country. This high population growth rate causes an increase in the demand for shelter and efficient supply and distribution of basic amenities and services for the city dwellers. In most urban centres in Nigeria, the problem of housing is not only restricted to quantity but also to the poor quality of available housing units [4]. There are strong indications that OSM has the capacity to deliver housing units at a faster speed and with higher quality compared to traditional construction [29-31]. For instance, in UK, aside from the fact that there was a move for change in the construction industry, OSM came into prominence after world wars 1 and 2 [32]. For OSM to be adopted in Nigeria, it is essential for barriers like lack of guidance and information, negative image etc. [16, 33] to be broken for Nigeria to fully enjoy the benefit of speed associated with OSM.

2.2. Skills Shortage

According to Chan and Dainty [34], the problem of skills shortage within the construction industry has been recurring over the past 30 years. This issue of skills shortage exists in almost all parts of the world to varying degrees, in the studies conducted by CIOB [35] and Schäfer [36], in UK and Germany respectively, it was identified that skills shortage existed in those countries. In the Nigerian context, Ayedun and Oluwatobi [1] identified skills shortage as one of the problems hampering the effective delivery of housing. One of the drivers to the uptake of OSM identified was skills shortage [29, 30, 37]. Since OSM takes away most of the construction processes to a controlled environment (factory), fewer operatives are needed because minimal work is done on site.

2.3. Unwillingness to Accept New Construction Practices

Ayedun and Oluwatobi [1] observed that the Nigerian Construction Industry as a whole was guilty of not accepting new technologies. This is also similar to the UK construction industry [38]. With the call for a shift from 'conventional' construction approaches to a more adaptable and faster way of construction [10], it is important for the Nigerian housing sector to put modalities in place for OSM to be incorporated into its structures. Adopting this method will not be easy, as there are several barriers associated with the uptake of OSM – as acknowledged in other countries where OSM is used [Fussell, Blismas [11], Goodier and Gibb [16], Arif, Bendi [29], Pan, Dainty [39], Jonsson and Rudberg [40], Rahman [41], Zhai, Reed [42]]. Housing delivery in developed and developing countries of the world are faced with many challenges. In the case of developing countries like Nigeria, the problems are multifarious compared to developed countries. The population of the world is increasing at an enormous rate and most of this increase is expected in developing countries [5, 43]. Acknowledging these statistics, it is important for developing countries to think of the way forward with regards to housing delivery.

3. Offsite Manufacturing and the Opportunity for its adoption in Nigeria

There are various terms and acronyms associated with OSM. They include OSM, manufactured construction, offsite construction (OSC), offsite production (OSP), pre-assembly, prefabrication, modern methods of construction (MMC) etc. and these terms are all used interchangeably [44-48]. For the purpose of this study, it will be referred to as OSM. Nadim and Goulding [38], argued that, offsite manufacturing falls under the broad umbrella of Modern Methods of Construction (MMC). Over the years, quite a number of definitions have been used to describe offsite manufacturing [46].

OSM can be defined as processes that incorporate prefabrication and pre-assembly to produce units and or modules that are then transported to site and positioned to form a permanent work [33, 37, 49, 50]. According to MBI [51], offsite manufacturing refers to any part or aspect of a construction process that is carried out in a controlled condition away from the actual site where the building is or will be situated. But Gibb and Pendlebury [52], went a step further and defined OSM as a term used to describe a range of applications where structures, buildings or parts are manufactured and assembled away from the site before they are finally installed into positions. In a nutshell, offsite manufacturing involves moving operations that are traditionally completed onsite to a manufacturing environment [52] and this in turn improves the quality, customer satisfaction, efficiency, predictability of delivery timescale and sustainability of project [38].

Several benefits are obtainable from the use/adoption of OSM. These benefits have been categorized into sustainable benefits and process and objective based benefits. These benefits were highlighted in the works of [Arif, Bendi [29], Pan, Dainty [39], Arif and Egbu [44], Taylor [46], 53, Pasquire, Gibb [54], Jaillon and Poon [55], Boyd, Khalfan [56], Haas, O'Connor [57]]. The benefits of offsite manufacturing are highlighted in Figure 1. Gorgolewski [53] identified the sustainable benefits of OSM, they are:

- Less Impact on the Surroundings

- Reduced Level of Defect
- Less Waste in Manufacture
- Transportation
- Greater Efficiency in the use of Resources, Both Materials and Labour

Pitt, Tucker [58] ascertained that 40 per cent of all UK waste (including greenhouse gas emission) is produced by the construction industry. It has also been observed that most of these wastes generated from construction sites are deposited in landfills [53]. Also, it was observed that, about 13 per-cent of materials delivered to sites are never used and are therefore turned into waste [53]. In the case of Nigeria, as opined by Ajayi, Koleoso [59], a large volume of waste is generated in an average Nigerian site. It was found out that most wastes were generated from demolition works on site and material handling. To reduce waste generated on site, based on a research conducted by WRAP [60], it was observed that between 70 per-cent and 90 per-cent of waste reduction could be achieved with the use of OSM (depending on the particular OSM process being adopted). Also, it is easier to gather and recycle waste generated from OSM compared to traditional construction methods [60]. Additional benefits in support of this position can be seen in Figure 1.

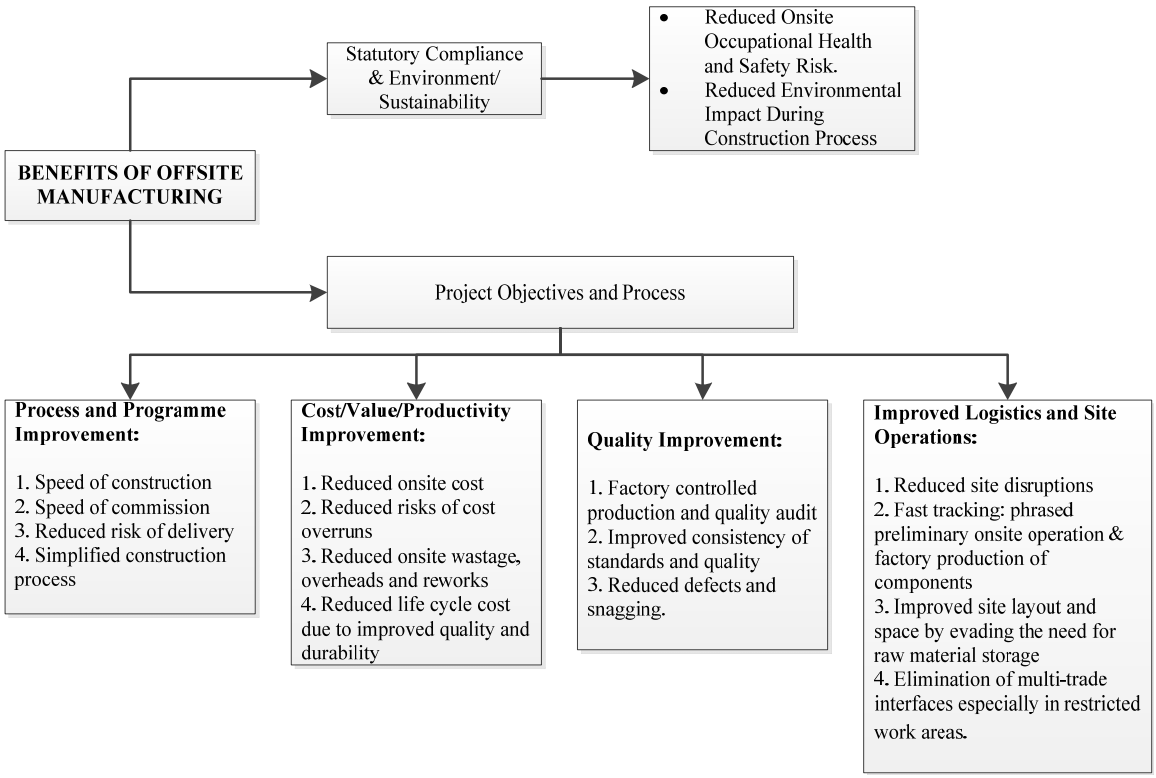

Fig. 1. Benefits of OSM [11]

3.1. Process and Programme Improvement

Gibb and Pendlebury [52] asserted that, “time is a big-plus for offsite”. The time spent on site depends on the amount of factory produced components and those produced traditionally [32]. Construction time is normally affected by material shortage, skills shortage and bad weather conditions. In the case of OSM, these issues have been addressed because most of the building components are manufactured in factories and transported to site, this

drastically reduces the amount of time spent on site [32]. As a result of the short time spent on site, it is easier to predict completion dates and also access restricted site areas, for example airport closures and school holiday [52]. As identified by Taylor [32], the issues of material shortage and weather were also found to be similar to Nigeria [61], as argued by Taylor [32] to tackle these issues, the use of OSM can be adopted, this will help reduce the overall time spent on projects. In the works of [Arif, Bendi [29], Blismas and Wakefield [30], Lu [31], Gibb and Isack [37]], it was observed that one of the most important benefits of OSM was time, i.e. reduction in the time spent on site and faster pace of delivery of projects.

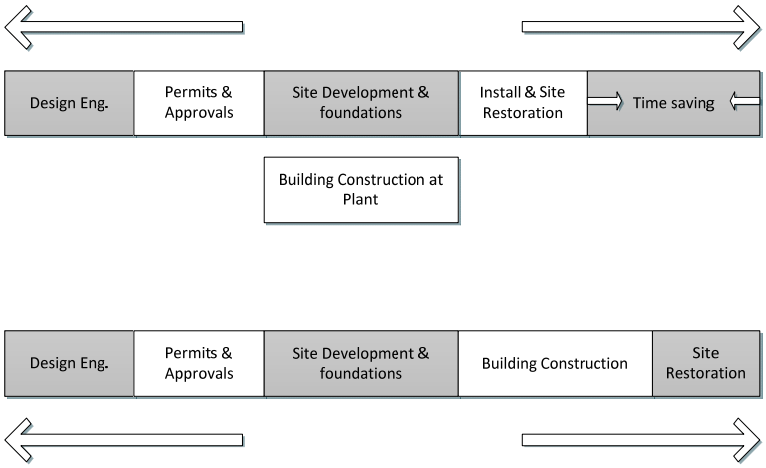

Fig. 2. Comparison between OSM Schedule and Site Built Construction Schedule [51]

Figure 2 identifies how time can be saved while using OSM as compared to site built construction. Based on the MBI [51] report, as a result of performing the site development and building construction at plant simultaneously, there is a 30 – 50 per-cent chance of finishing buildings faster. For professionals involved in construction especially project managers, having a method that improves quality of construction projects and reduces the overall time is indeed a great advantage.

3.2. Cost/Value and Productivity Improvement

OSM is believed to be more expensive than more established techniques (traditional method) NationalAuditOffice [62]. But Gibb and Pendlebury [52] argued that, savings from OSM can be achieved in the areas of cost certainty and reduced risk, less overall life cycle costs, better quality of building which will in-turn lead to reduced maintenance cost, reduced preliminaries and site overhead, reduced construction time which can result in cost benefit from early occupation of the property. According to WRAP [60], based on research conducted, it was observed that savings can be achieved by using OSM due to a reduction in waste of building materials especially bricks. In Nigeria were sandcrete blocks/bricks are generally used, incorporating OSM will go a long way in reducing waste on site.

3.3. Quality Improvement

As argued by the NationalAuditOffice [62], OSM meets the three quality requirements of durability, whole life cost and performance. In the works of [Fussell, Blismas [11], Arif, Bendi [29], Gibb and Isack [37]], based on researches conducted in India, Australia and UK respectively, it was realised that achieving greater quality was one of the major benefits of OSM and also one of the key drivers to its adoption in those countries. Quality can better be achieved within a factory and also, products consistency can be better achieved while working in a controlled

environment (factory) [37]. The problem of housing in Nigeria is not only in terms of quantity but also quality [20], as such adopting OSM will improve housing delivery efforts in terms of quantity and quality.

3.4. Improved Logistics and Site Operations

Reduction in wet trades, site disruptions and having more certainty over the control of projects, was found to be an important benefit of OSM [37]. A good example cited by Gibb and Isack [37] is, working in a prison, were contractors have to be escorted to and from their site and all employees have to be properly scrutinised, but if OSM is adopted, the amount spent on security will be reduced as less time will be spent on site by the contractor. Also in the case of airports, roads and rail projects, site access and working space are normally limited; as a result, OSM was seen to be of great benefit. OSM is a construction technique that has been adopted in a good number of countries for different reasons. In Nigeria, the current housing deficit demands that housing units need to be provided at a faster speed and from the experiences of other countries, OSM can deliver housing units faster and with superior quality compared to traditional construction.

4. Discussion

There are numerous factors hindering housing delivery in Nigeria [21]. One of the factors identified was high population growth [28]. As a result of rapid increase in population, there is pressure on the available housing stock. As stated by [Arif, Bendi [29], Lu [31], Gibb and Pendlebury [52]], time is a big plus for OSM, as such the use of OSM by the Nigerian housing sector will help increase the speed of housing delivery. There are indications that OSM can save the time spent on construction by about 30 – 50 per-cent compared to traditional construction technique [51]. OSM will go a long way in making housing delivery in Nigeria faster than it is currently.

Another problem of housing delivery in Nigeria as identified by Ayedun and Oluwatobi [1] was skills shortage. The current situation in Nigeria suggests that there is a shortage in manpower necessary for adequate delivery of the needed housing units. One of the drivers to the uptake of OSM in some developed countries was skills shortage [29, Blismas and Wakefield [30], Gibb and Isack [37]]. Since OSM requires fewer tradesmen [30], its adoption will eliminate the problem of skills shortage and as such, the possibility of meeting the demand for housing can be met with the few tradesmen available.

The issue of unwillingness to innovate is one that is associate with the construction industry all over the world, Ayedun and Oluwatobi [1] identified this problem with the Nigerian construction industry. OSM is a construction technique that is being used in a number of countries as various counties have found different reasons to adopt OSM into their construction processes. Based on the current situation in Nigeria, there are a good number of reasons to incorporate OSM, i.e. to improve housing delivery, to follow the trend that worked in developed countries etc. For OSM to be adopted in Nigeria, efforts need to be put by all the stakeholders involved in construction.

As much as there are many benefits associated with OSM, there are some barriers that have been found to hinder its uptake [Fussell, Blismas [11], Goodier and Gibb [16], Arif, Bendi [29], 39, Jonsson and Rudberg [40], Rahman [41], Zhai, Reed [42]]. Some barriers that have been found to hinder the uptake of OSM include; Negative Image, Reluctance to Innovate, Perception of Stakeholders, Perceived High Cost, Quality of Such Buildings etc.

Goodier and Gibb [16] identified negative image as one of the barriers to the uptake of OSM and for the Nigeria housing sector to adopt OSM, it will need to present a good image about OSM. Arif, Goulding [63] suggested that the OSM industry should focus more on visualization and simulation technologies as a means of creating awareness on OSM. When people see what is achievable using OSM, it is easier for it to be accepted.

The uptake of OSM is influenced by the perception of housing developers as to the advantage and disadvantage of OSM [39]. The issue of perception does not only lie on the developers, surveyors are also not familiar with OSM, as such, they do not really understand how to asses such properties [39]. Also, customers/clients are not really aware

of what OSM is all about and as a result, they are more inclined to the traditional method of construction, making it difficult for OSM to be adopted. For OSM to be adopted in Nigeria, it is important for the Nigerian housing sector to critically study and consult with experts who are into the use of OSM in developed countries.

5. Conclusion

With a housing deficit of about 17 million, it is necessary for housing units to be delivered at a faster pace to meet demand (to address this housing deficit). From the experiences of other countries, OSM has the potential of improving housing delivery in terms of speed, quantity and quality. In addition, it is recognised that OSM typically requires fewer trade-operatives compared to traditional method of construction. As such, the problem of skills shortages could be more readily managed with the adoption of OSM. Even though OSM has so many benefits, it is equally important to note that certain barriers are known to exist that can hinder its uptake in other countries. Some of these barriers include; negative image, perceived high cost, perception of stakeholders etc. For the Nigerian housing sector to incorporate OSM into its construction processes, it is important to learn from the experiences of these other countries that have already incorporated OSM into their construction processes. Government intervention through Research and Development could be one such way of improving housing delivery. Additionally, the use of Building Information Modelling (BIM) could be used to support OSM in overcoming some of OSM's weaknesses. Evidence to date has highlighted that OSM is still largely unknown in the Nigeria Construction industry. As such, additional work is needed to improve market penetration. Nigeria has the potential to leverage the collective experiences of other countries (in OSM) in a meaningful way in order to address its current housing delivery shortfall.

References

[1] Ayedun, C.A. and A.O. Oluwatobi, Issues and Challenges Militating against the Sustainability of Affordable Housing Provision in Nigeria. Business Management Dynamics, 2011. **1**(4): p. 1 - 8.
[2] Akeju, A.A., Challenges to Providing Affordable Housing in Nigeria, in 2nd Emerging Urban Africa International Conference on Housing Finance in Nigeria. 2007: Shehu Musa Yar'adua Center Abuja.
[3] Makinde, O.O., Housing Delivery System, Need and Demand. Environment, Development and Sustainability, 2014. **16**(1): p. 49 - 69.
[4] Kabir, B. and S.A. Bustani, A Review of Housing Delivery Efforts in Nigeria, in ISA International Housing Conference. 2009: University of Glasgow, Scotland.
[5] Ademiluyi, I.A., Public Housing Delivery Strategies in Nigeria: A Historical Perspective of Policies and Programmes. . Journal of Sustainable Development in Africa, 2010. **12**(6): p. 153 - 161.
[6] Ukwayi, J.K., et al., An Assessment of Housing Delivery in Nigeria: Federal Mortgage Bank Scenario. Canadian Social Science, 2012. **8**(6): p. 68 - 74.
[7] Wolstenholme, A., Never Waste a Good Crisis: A Review of Progress since Rethinking Construction and Thought for the Future. 2009, Constructing Excellence: Warwick House, London. p. 31.
[8] Nkah, V., Nigeria's housing deficit: Balancing the equation, in The Economy. 2013: Lagos.
[9] Ashkin, R., Innovative Building Technologies – The Social Housing Angle, in Housing Africa 2013. 2013: Abuja, Nigeria.
[10] Dada, A., Housing deficit: Experts canvass new construction system, in The Punch. 2013, Ajibola Ogunsola: Lagos.
[11] Fussell, T., et al., Offsite Manufacture in Australia. 2007, Cooperative Research Centre for Construction Innovation: Brisbane, Australlia. p. 82.
[12] Experian and SamiConsulting, 2020 Vision – The Future of UK Construction. 2008, ConstructionSkills. p. 87.
[13] Blismas, N., R. Wakefield, and B. Hauser, Concrete prefabricated housing via advances in systems technologies: Development of a technology roadmap. Engineering, Construction and Architectural Management, 2010. **17**(1): p. 99 -110.
[14] Azman, M.N.A., et al., Perspective of Malaysian Industrialized Building System on the Modern Method of Construction, in 11th Asia Pacific Industrial Engineering and Management Systems Conference. 2010: Melaka, Malaysia.
[15] Smith, R.E., History of Prefabrication: A Cultural Survey, in Third International Congress on Construction History. 2009: Cottbus, Germany.
[16] Goodier, C. and A. Gibb, Barriers and opportunities for offsite in the UK. Abdul Samed Kazi (ed). Systematic Innovation in the Management of Project and Processes, cib Helsinki International Joint Symposium, 2005: p. 144 - 158.
[17] PrefabNZIncorporated, Prefab Roadmap: A Way Forward for Prefabrication in New Zealand (2013-2018). 2013, PrefabNZ Incorporated: Wellington. New Zealand. p. 1 - 29.
[18] McGraw-HillConstruction, Prefabrication and Modularization: Increasing Productivity in the Construction Industry, in SmartMarket Report, E. Fitch, Editor. 2011: Bedford, Massachusetts, USA.

[19] Brock, L. and J. Brown, The Prefabricated House in the Twenty-First Century: What Can We Learn from Japan? A Case Study of the KST-Hokkaido House, in World Conference on Timber Engineering. 2000: Whistler Resort, British Columbia, Canada.
[20] Olayiwola, L.M., O. Adeleye, and L. Ogunshakin, Public Housing Delivery In Nigeria: Problems And Challenges, in World congress on Housing. 2005: Pretoria, South Africa.
[21] Emmanuel, J.B., "Housing Quality" To the Low Income Housing Producers in Ogbere, Ibadan, Nigeria. Procedia - Social and Behavioral Sciences, 2012. **35**(0): p. 483-494.
[22] Ogu, V.I. and J.E. Ogbuozobe, Housing policy in Nigeria: towards enablement of private housing development. Habitat International, 2001. **25**(4): p. 473-492.
[23] Oladapo, M.A., Procurement Systems and Project Organisation Model for Low Cost Housing, in FIG XXII International Congress. 2002: Washington, D.C. USA.
[24] Subair, G., Nigeria has N59trn housing deficit in Nigerian Tribune. 2013.
[25] Adenuga, O.A., Factors Affecting Quality in the Delivery of Public Housing Projects in Lagos State, Nigeria. International Journal of Engineering and Technology, 2013. **3**(3): p. 332 - 344.
[26] Suleiman, M., Nigeria: Stakeholders Identify Factors Against Affordable Housing, in Daily Trust. 2013, Media Trust.
[27] Olotuah, A.O. and A.O. Ajenifujah, Architectural Education and Housing Provision in Nigeria. CEBE Transactions, 2009. **6**(1): p. 86 - 102.
[28] Akinmoladun, O.I. and J.O. Oluwoye, An Assessment of why the Problems of Housing Shortage Persist in Developing Countries: A Case Study of Lagos Metropolis, Nigeria. Pakistan Journal of Social Science, 2007. **4**(4): p. 587 - 598.
[29] Arif, M., et al., State of offsite construction in India-Drivers and barriers. Journal of Physics: Conference Series, 2012. **364**(1): p. 012109.
[30] Blismas, N. and R. Wakefield, Drivers, constraints and the future of offsite manufacture in Australia. Construction Innovation, 2009. **9**(1): p. 72-83.
[31] Lu, N. The Current Use of Offsite Construction Techniques in the United States Construction Industry. in Construction Research Congress. 2009.
[32] Taylor, S., Off-site Production in the UK Construction Industry - A Brief Overview. 2009, Buildoffsite.
[33] Jaillon, L. and C.S. Poon, Sustainable construction aspects of using prefabrication in dense urban environment: a Hong Kong case study. Construction Management and Economics, 2008. **26**(9): p. 953-966.
[34] Chan, P.W. and A.R.J. Dainty, Resolving the UK construction skills crisis: a critical perspective on the research and policy agenda. Construction Management and Economics, 2007. **25**(4): p. 375-386.
[35] CIOB, Skills Shortages in the UK Construction Industry. 2008, Chartered Institute of Building: Berkshire.
[36] Schäfer, D., Skills shortage threatens German engineering, in Financial Times. 2010, Pearson PLC: London.
[37] Gibb, A. and F. Isack, Re-engineering through pre-assembly: client expectations and drivers. Building Research & Information, 2003. **31**(2): p. 146-160.
[38] Nadim, W. and J.S. Goulding, Offsite production in the UK: the way forward? A UK construction industry perspective. Construction Innovation: Information, Process, Management, 2010. **10**(2): p. 181 - 202.
[39] Pan, W., A.R.J. Dainty, and A.G.F. Gibb. Managing innovation: a focus on off-site production (osp) in the UK housebuilding industry. in 20th Annual ARCOM Conference. 2004. Heriot Watt University, Edinburgh, Scotland
[40] Jonsson, H. and M. Rudberg, Classification of production systems for industrialized building: a production strategy perspective. Construction Management and Economics, 2013: p. 1-17.
[41] Rahman, M., Barriers of Implementing Modern Methods of Construction. Journal of Management in Engineering, 2013. **0**(ja): p. null.
[42] Zhai, X., R. Reed, and A. Mills, Factors impeding the offsite production of housing construction in China: an investigation of current practice. Construction Management and Economics, 2013: p. 1-13.
[43] Sivam, A., et al., An approach to improved housing delivery in large cities of less developed countries. Habitat International, 2001. **25**(1): p. 99-113.
[44] Arif, M. and C. Egbu, Making a Case for Offsite Construction in China. Engineering, Construction and Architectural Management, 2010. **17**(6): p. 536 - 548.
[45] Goodier, C. and A. Gibb, Future opportunities for offsite in the UK. Construction Management and Economics, 2007. **25**(6): p. 585-595.
[46] Taylor, M.D., A definition and valuation of the UK offsite construction sector. Construction Management and Economics, 2010. **28**(8): p. 885-896.
[47] Goulding, J. and M. Arif, Offsite Production and Manufacturing – Research Roadmap Report, W. Bakens, Editor. 2013, International Council for Research and Innovation in Building and Construction (CIB).
[48] Goulding, J.S., et al., New offsite production and business models in construction: priorities for the future research agenda. Architectural Engineering and Design Management, 2014: p. 1 - 22.
[49] Gibb, A., Off-site fabrication: prefabrication, pre-assembly and modularisation. 1999: Wiley.
[50] Emmitt, S. and C. Gorse, Barry's Advanced Construction of Buildings. 2 ed. 2010, Chichester: Wiley-Blackwell.
[51] MBI, Improving Construction Efficiency & Productivity with Modular Construction. 2010, Modular Building Institute: Charlottesville, Virginia, USA. p. 1 - 16.
[52] Gibb, A. and M. Pendlebury, Buildoffsite Glossary of Terms. 2006, Buildoffsite.
[53] Gorgolewski, M., Offsite fabrication, in Green Building Magazine. 2003, Green Building Press.
[54] Pasquire, C., A. Gibb, and N. Blismas. Off-site production: evaluating the drivers and constraints. in 12th Annual Conference of the International Group for Lean Construction, Helsingore, August. 2004. Department of Building, National University of Singapore.
[55] Jaillon, L. and C.S. Poon, Design issues of using prefabrication in Hong Kong building construction. Construction Management and Economics, 2010. **28**(10): p. 1025-1042.

[56] Boyd, N., M. Khalfan, and T. Maqsood, Off-Site Construction of Apartment Buildings. Journal of Architectural Engineering, 2013. **19**(1): p. 51-57.
[57] Haas, C.T., et al., Prefabrication and Preassembly Trends and Effects on the Construction Workforce. 2000, Center for Construction Industry Studies: Austin, Texas. p. 1 - 30.
[58] Pitt, M., et al., Towards sustainable construction: promotion and best practices. Construction Innovation: Information, Process, Management, 2009. **9**(2): p. 201 - 224.
[59] Ajayi, O.M., et al. The Practice of Waste Management in Construction Sites in Lagos State; Nigeria. in The construction and building research conference of the Royal Institution of Chartered Surveyors. 2008. Dublin Institute of Technology, Ireland.
[60] WRAP, Current Practices and Future Potential in Modern Methods of Construction. 2007, WRAP: Banbury, Oxon. p. 1 - 21.
[61] Mansfield, N.R., O.O. Ugwu, and T. Doran, Causes of delay and cost overruns in Nigerian construction projects. International Journal of Project Management, 1994. **12**(4): p. 254-260.
[62] NationalAuditOffice, Using modern methods of construction to build homes more quickly and efficiently. 2005, National Audit Office: Victoria, London.
[63] Arif, M., J. Goulding, and F. Rahimian, Promoting Off-Site Construction: Future Challenges and Opportunities. Journal of Architectural Engineering, 2012. **18**(2): p. 75-78.